Example 2h: External Material Database

This example problem employs the external material database capabilities of MAC/GMC 4.0. This material database provides users with another option for storing their constituent material properties – in an external ASCII file rather than directly in the input file. Users can thus construct their own database of material properties in a single (or multiple) file(s) and access them from MAC/GMC 4.0 at will. To reference a particular external material database file from a MAC/GMC 4.0 input file, the additional keyword, ***MDBPATH**, is specified. It is clear from the contents of the external material database ASCII file (given below) that the format of this file is similar to that of the ***CONSTITUENTS** section of the input file. The main difference is that the information for each material in the external file begins with the line `MAT=*`, which specifies the name of the material. This name is the referenced in the input file in the ***CONSTITUENTS** section. The only other difference in the form of the external material database is that the line following the material name specification line specifies the constitutive model for the material (`CMOD=*`). The material constitutive model is also specified for each material in the input file, and the constitutive model specified in both files must match, or an error will occur. For more information on the external material database capabilities, see the MAC/GMC 4.0 Keywords Manual Section 2.

MAC/GMC Input File: **example_2h.mac**

```
MAC/GMC 4.0 Example 2h - External Material Database
*MDBPATH
  NAME=sample_material_database.mat
*CONSTITUENTS
  NMATS=3
  M=1 CMOD=1  MATID=U MATDB=3 EXTMAT=copper
  M=2 CMOD=99 MATID=U MATDB=3 EXTMAT=Al(6061-0)
  M=3 CMOD=6  MATID=U MATDB=3 EXTMAT=SCS-6
*RUC
# -- Alter value of M=* to change simulated material
  MOD=1 M=1
*MECH
  LOP=1
  NPT=2 TI=0.,200. MAG=0.,0.02 MODE=1
*THERM
  NPT=2 TI=0.,200. TEMP=23.,23.
*SOLVER
  METHOD=1 NPT=2 TI=0.,200. STP=0.02
*PRINT
  NPL=6
*XYPLOT
  FREQ=20
  MACRO=1
   NAME=example_2h X=1 Y=7
  MICRO=0
*END
```

External Material Database File:

sample_material_database.mat

```
Sample Material Database Provided with MAC/GMC 4.0
#
# ------- Bodner-Partom Model Material
MAT=copper
 CMOD=1
 EL=120.E9,120.E9,0.33,0.33,45.11E9,14.7E-6,14.7E-6 &
 VI=1.E4,63.E6,250.E6,8.19,7.5,0.55
#
# ------- Isotropic, Elastic Materials
MAT=SCS-6
 CMOD=6
 NTP=5
 TEM=21.0,316.0,427.0,538.0,860.0
 EA=393.E9,382.E9,378.E9,374.E9,368.E9
 ET=393.E9,382.E9,378.E9,374.E9,368.E9
 NUA=0.25,0.25,0.25,0.25,0.25
 NUT=0.25,0.25,0.25,0.25,0.25
 GA=157.2E9,152.8E9,151.2E9,149.6E9,147.2E9
 ALPA=3.56E-6,3.73E-6,3.91E-6,4.07E-6,4.57E-6
 ALPT=3.56E-6,3.73E-6,3.91E-6,4.07E-6,4.57E-6
#
# ------- User constitutive model example
MAT=Al(6061-0)
 CMOD=99
 NPE=2 NPV=6
 NTP=6
 TEM=21.0,148.9,204.4,260.0,371.1,400.0
 E1=72.5E9,69.4E9,65.8E9,58.5E9,41.5E9,41.5E9
 E2=0.33,0.33,0.33,0.33,0.33,0.33
 ALPA=22.5E-6,22.5E-6,22.5E-6,22.5E-6,22.5E-6,22.5E-6
 ALPT=22.5E-6,22.5E-6,22.5E-6,22.5E-6,22.5E-6,22.5E-6
 V1=1.E4, 1.E4, 1.E4, 1.E4, 1.E4, 1.E4
 V2=100.E6,100.E6,100.E6,100.E6,100.E6,100.E6
 V3=190.E6,190.E6,190.E6,190.E6,190.E6,190.E6
 V4=70.0,70.0,70.0,70.0,70.0,70.0
 V5=10.0,7.0,4.0,1.6,0.55,0.55
 V6=0.4,0.4,0.4,0.4,0.4,0.4
```

Annotated Input Data

1) Flags: None

2) Constituent material information
   a) External material database file specification (**`*MDBPATH`**) [KM_2]:
      Name of external database file: sample_material_database.mat
      (`NAME=sample_material_database.mat`)

   b) Constituent materials to include for code execution (**`*CONSTITUENTS`**) [KM_2]:

Number of materials:	3	(NMATS=3)
Constitutive models:	Bodner-Partom	(CMOD=1)
	User-defined	(CMOD=99)
	Linear Elastic	(CMOD=6)
Materials:	All User-defined:	(MATID=U)
	Copper	(EXTMAT=copper)
	Al 6061-0	(EXTMAT=Al(6061-0))
	SCS-6 fiber	(EXTMAT=SCS-6)
Material property source:	External material database	(MATDB=3)

3) Analysis type (***RUC**) → Repeating Unit Cell Analysis [KM_3]:

Analysis model:	Monolithic material	(MOD=1)
Material assignment:	Each constituent successively	(M=*)

4) Loading:

a) Mechanical (***MECH**) [KM_4]:

Loading option:	1	(LOP=1)
Number of points:	2	(NPT=2)
Time points:	0., 200. sec.	(TI=0.,200.)
Load magnitude:	0., 0.02	(MAG=0.,0.02)
Loading mode:	strain control	(MODE=1)

b) Thermal (***THERM**) [KM_4]:

Number of points:	2	(NPT=2)
Time points:	0., 200. sec.	(TI=0.,200.)
Temperature points:	23., 23. °C	(TEMP=23.,23.)

c) Time integration (***SOLVER**) [KM_4]:

Time integration method:	Forward Euler	(METHOD=1)
Number of points:	2	(NPT=2)
Time points:	0., 200. sec.	(TI=0.,200.)
Time step sizes:	0.02 sec.	(STP=0.02)

5) Damage and Failure: None

6) Output:

a) Output file print level (***PRINT**) [KM_6]:

Print level:	6	(NPL=6)

b) x-y plots (***XYPLOT**) [KM_6]:

Frequency:	20	(FREQ=20)
Number of macro plots:	1	(MACRO=1)
Macro plot names:	example_2h	(NAME=example_2h)
Macro plot x-y quantities:	ε_{11}, σ_{11}	(X=1 Y=7)
Number of micro plots:	0	(MICRO=0)

7) End of file keyword: (***END**)

Results

The results for this example problem, in the form of the three stress-strain curves for the three constituent materials, are given in Figure 2.12. It is again important to note that, since the Al 6061-0 material employs the distributed version of the `usrmat.F90` subroutine and the `usrformde.F90` subroutine, if an altered version of these subroutines is called by MAC/GMC 4.0, this example problem may not execute correctly.

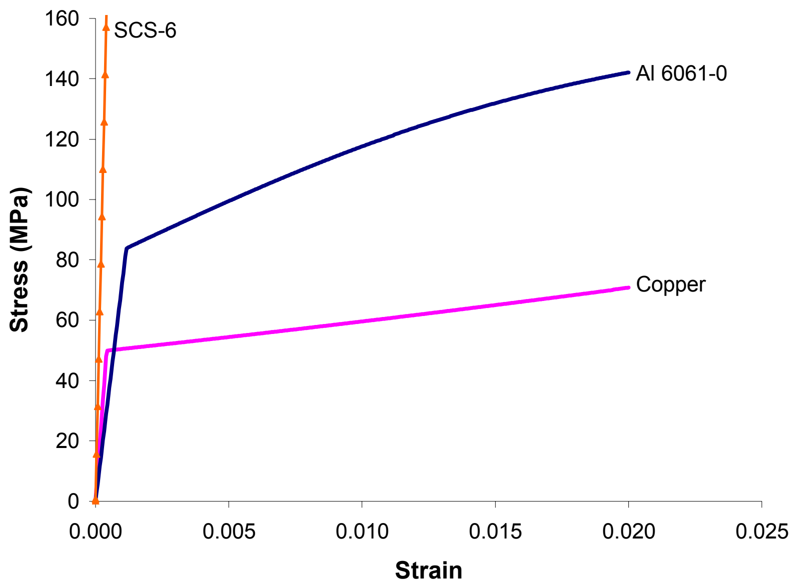

Figure 2.12 Example 2h: plot of the tensile stress-strain response for three materials taken from the external material database.